

Clinical Performance and Epidemiologic Aspects of Fractured Anterior Teeth Restored with a Composite Resin: A Two-Year Clinical Study

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Abstract

Purpose: To investigate the etiologic factors, effect of age and gender on dental trauma, and to evaluate the performance of composite resin on the fractured crown of permanent anterior teeth.

Materials and Methods: Over a 2-year period, 73 permanent teeth from 51 patients with dental trauma were treated with direct composite resin restoration. Informed consent and standardized trauma forms were completed by the patient; teeth were restored with a submicron hybrid composite resin (Spectrum TPH) and respective adhesive system (Prime&Bond NT). Sixty-nine teeth were directly restored without fiber posts, while four were treated with fiber posts. Two experienced clinicians, besides the operator, evaluated each restoration at 6-, 12-, and 24-month follow-ups according to US Public Health Service (USPHS) criteria for the following characteristics: anatomical form, marginal adaptation, color match, marginal discoloration, surface roughness, and caries. Data were analyzed using the Wilcoxon Signed Rank, Kruskal-Wallis, Mann-Whitney U, and Siegel and Castellan tests.

Results: A total of 73 traumatized teeth in 51 patients aged from 14 to 64 years (mean age 25.47 ± 14.058 years) were assessed according to the Ellis classification and restored over a 2-year period. Crown fractures were more common in the maxilla (84.9%) and caused by falls (58.8%). At the end of 24 months, a total of ten restorations were lost. The survival rate after 24 months was 82.14%. There were statistically significant differences in marginal adaptation between the 6-, 12-, and 24-month follow-ups. Although changes in marginal discoloration over time were not significant ($p = 0.194$), changes in color match were significant ($p = 0.029$).

Conclusion: Within the limitations of this study, direct composite restorations were accepted as clinically satisfactory.

Oro-facial trauma that results in fractured, displaced, or lost teeth has a significant negative effect on a patient's appearance and on tooth function.^{1,2} These traumas are more common in children.^{3,4} The common risk factors are falls, automobile/bicycle accidents, collisions, gender, age,⁵⁻⁷ behavioral characteristics,^{8,9} and physical activity.¹⁰

Anterior teeth esthetics have been reported to be an important aspect of human appearance and could be affected by many factors, including the presence of restorations, tooth color, position, alignment, and shape.¹¹⁻¹⁵ Dental trauma of permanent incisors and their supporting tissues occurs due to different reasons and needs immediate assessment and management for psychological and physical reasons,⁸ particularly in the case of continually developing young permanent teeth. Trauma involving anterior teeth may cause pain and affect speaking, chewing, and esthetic satisfactions of patients.¹⁶

Nonetheless, the treatment of dental trauma is sometimes neglected.¹⁷⁻¹⁹

A number of techniques have been introduced regarding treatment of traumatized permanent anterior teeth.²⁰ These techniques include reattachment of fractured tooth fragments, pin-retained restorations, full-coverage crowns, and direct composite resin restorations.²¹ Reattachment could be the preferred technique in light of the modern minimally invasive treatment concept.^{21,22} However, some disadvantages have been reported in the literature. It was reported that new trauma can increase the risk of debonding and re-fracture.²³ Full-coverage crowns with different materials are another treatment option. Although this treatment method may yield high esthetics, it is inconsistent with the minimally invasive treatment concept, since it requires more tooth preparation. Marginal fit discrepancies can affect long-term success, cause plaque accumulation, secondary

caries, and periodontal inflammation.²⁴ Advances in adhesive technology and esthetic properties of composite resins allow clinicians a conservative method of restoring fractured anterior teeth. Monochromatic direct treatment restorations have been reported to be a common approach in the treatment of fractured anterior teeth because they are conservative, predictable, repairable, and inexpensive.²⁵

There is no literature related to long-term clinical follow-up of fractured anterior teeth restored with direct composite resin restoration. This clinical study was performed to investigate the etiologic factors, effects of age and gender on dental trauma, and to evaluate the performance of composite resin on the fractured crowns of permanent anterior teeth 6, 12, 18, and 24 months after initial restoration.

Materials and methods

The study participants were nonhospitalized, 51 volunteer patients (aged between 14 and 64 years) with 73 traumatized permanent anterior teeth. They applied to the restorative dental clinic of a dental school with complaints of pain and/or esthetic problems due to the trauma. The teeth were randomly selected for this study during February 2012 to May 2014. The inclusion criteria were: voluntary participation and signed written informed consent forms; willingness to participate in the recall appointments; the teeth to be restored should be permanent and have Ellis I, II, or III crown fractures without root fractures; in case of Ellis C III fractures, the ferrule heights should be at least 2 mm. This clinical study was approved by the Hacettepe University, Clinical Researches Ethics Boards with the reference number GO 16/505-17 and was conducted in full accordance with the World Medical Association Declaration of Helsinki. Consent was obtained from the parents/guardians of participants who were under 18 years of age.

A clinical examination was performed by two experienced clinicians together with the operator (UKV). Periapical dental radiographs were obtained for each traumatized tooth. Before the clinical examination, wet gauze pads were used to clean tooth surfaces, and visual examinations were conducted. Age, gender, time and cause of the injury, time elapsed between trauma and treatment, number of tooth affected, tooth sensitivity, and other related information were recorded on standardized trauma forms. The type of trauma was recorded according to the Ellis classification: class I includes only enamel fracture; class II includes enamel and dentin fractures; and class III includes enamel and dentin fractures with pulp tissue exposure and required endodontic treatment.¹⁹ Root fractures were not included in this study. The same operator performed all the treatments to standardize the restoration protocol.

The treatment was started with cleaning the tooth surfaces using a slurry of pumice. The tooth color was detected using Vita Easyshade guide (Vita Zahnfabrik, Bad Sackingen, Germany). In the case of Ellis III crown fractures, the tooth was first endodontically treated by conventional methods. Four of five endodontically treated teeth received fiber posts (Fig 1). At circumferential bevel level, a minimum 2 mm dentin was maintained to obtain an optimal ferrule effect. Fiber posts were not placed into the one root canal treated tooth, because the fracture type was oblique, and remaining tooth structure was sufficient

Table 1 Materials used

Material	Composition
Spectrum TPH (Dentsply DeTrey, Konstanz, Germany)	<ul style="list-style-type: none"> • Bis-GMA-adduct (adduct of 2,2-Bis[4-(2-hydroxy-3-methacryloyloxypropoxy)-phenyl]propane with hexamethylene diisocyanate) • Bis-EMA (2,2-Bis[4-(2-methacryloyloxyethoxy)-phenyl]propane) • TEGDMA (3,6-dioxaoctamethylene dimethacrylate) • Photoinitiators • Stabilizers • Barium aluminium borosilicate (mean particle size <1.5 μm) • Highly dispersed silicon dioxide (particle size 0.04 μm)
Prime & Bond NT (Dentsply International, York, PA)	<ul style="list-style-type: none"> • Di- and trimethacrylate resins • Functionalized amorphous silica • PENTA (dipentaerythritol penta acrylate monophosphate) • Photoinitiators • Stabilizers • Cetylamine hydrofluoride • Acetone

to retain direct composite resin restoration. In the case of Ellis I and II crown fractures, an extended bevel was prepared using sterile diamond burs at high speed under water cooling on both the facial and palatal surfaces to allow for a gradual increase in the resin composite thickness. Incisal edges and corners were rounded. No features were created to provide mechanical retention.

The materials used in this study are presented in Table 1. The enamel was etched with 37% phosphoric acid for 30 seconds and with dentin for 15 seconds and rinsed thoroughly with water. Excess water was removed with an air syringe. Isolation was performed using a saliva ejector and cotton rolls. The adhesive (Prime&Bond NT) was applied using a microbrush during the whole preparation and gently dried with an air syringe for 5 seconds. After leaving a shiny surface, it was LED light-cured for 20 seconds (Led Max 5 Hilux; Benlioglu Dental, Ankara, Turkey) set at 500 to 700 mW/cm² intensity. The teeth were restored with a submicron hybrid resin composite (Spectrum TPH). The composite resin was placed using the incremental technique in 2 mm layers and light polymerized for 20 seconds. All restorations were finished with extra/ultra-fine composite finishing burs (Diatech Dental AC, Heerbrugg, Switzerland) and polished with discs (SwissFlex; Diatech Dental AC). The Enhance PoGo Complete Kit (Dentsply, York, PA) was used to polish the palatal surface. Interproximal areas were examined using dental floss. Occlusion was evaluated by the help of lateral and protrusive movements of the mandible. Any necessary equilibration was accomplished with a finishing bur, and the final polishing procedure was repeated.

Restorations were evaluated by two experienced clinicians together with the operator, at the end of the first week (baseline) and at the 6-, 12-, 18-, and 24-month follow-ups. To detect

Table 2 Etiology of traumatic dental injuries by gender

Etiology of traumatic dental injuries	Gender						<i>p</i>
	Female		Male		Total		
	n	%	n	%	n	%	
Falls	14	27.5	16	31.4	30	58.8	0.559
Collision with people	2	3.9	4	7.8	6	11.8	
Bicycle accident	0	0.0	2	3.9	2	3.9	
Sports accident	1	2.0	2	3.9	3	5.9	
Traffic accident	1	2.0	1	2.0	2	3.9	
Struck by an object	6	11.8	2	3.9	8	15.7	
Total	24	47.1	27	52.9	51	100.0	

Table 3 Etiology of dental trauma by age

Age	Falls		Collision with people		Bicycle accident		Sports accident		Traffic accident		Struck by an object		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
14-16	11	21.5	1	2.0	1	2.0	2	4.0			1	2.0	16	31.4
17-24	9	17.7	4	7.8	1	2.0	1	2.0	1	2.0	2	3.9	18	35.2
25-64	10	19.6	1	2.0	–	–	–	–	1	2.0	5	9.8	17	33.3
Total	30	58.8	6	11.8	2	3.9	3	5.9	2	3.9	8	15.7	51	100

any signs of inflammation, clinical examination was performed using thermal testing by an air–water syringe, palpation and percussion tests, and electric pulp testing (Parkell, Farmingdale, NY). All restorations were evaluated according to the following USPHS criteria: vitality, percussion sensitivity, sensitivity to cold air, color match, marginal adaptation, anatomic form, surface roughness, marginal discoloration, and secondary caries. Two investigators evaluated the restorations. In case of disagreement, a senior researcher examined the restorations until reaching a consensus with the other study investigators.

All statistical analyses were performed using SPSS v21.0 package. The Fisher's exact or Pearson's Chi-square tests were used to analyze differences between two parameters at 5% significance level. Intragroup comparisons of baseline, 6-, 12-, 18-, and 24-month values were also performed. Differences in evaluated parameters on restorations over time were analyzed using the Cochran test.

Results

In this study, there were 73 restorations in 51 patients. Twenty-seven males and 24 females, with a mean age of 25.47 ± 14.058 years, were observed with trauma in a 2-year study period. The male/female ratio was 1.125/1. Recall rates were 100% at the 6- and 12-month, 90.19% at the 18-month, and 86.27% at the 24-month follow-ups. Four patients (who received five restorations) missed the 18-month follow-up, and one patient (who received two restorations) missed the 24-month follow-up.

Frequency of dental trauma was higher in males than in females, but it was not statistically significant ($p = 0.674$). The relationship between the cause of trauma and gender was not statistically significant ($p = 0.559$) (Table 2).

Dental trauma etiology according to age is presented in Table 3. In all age groups, falls were the main cause (58.8%) of dental trauma ($p < 0.0001$).

Patients arrived at the clinic for dental assessment from the 1st day to 58 years after trauma. Crown fractures were more common in the maxilla and equally distributed between the right and left side (Table 4). Thirty-one patients had one (60.8%), 18 patients had two (35.3%), and two patients had three (3.9%) fractured teeth due to trauma. The most common crown fracture was Ellis II, which was statistically significant ($p < 0.001$).

According to USPHS criteria, retention rate was 98.6% at the 6-month, 91.78% at 12-month, 85.29% at 18-month, and 82.14% at 24-month follow-up appointments. One patient (male) lost one restoration, three patients (2 males, 1 female) lost five restorations, and three patients (2 males, 1 female) lost four restorations after 6, 12, and 18 months, respectively. Debonding of the restorations was mostly observed between 12 and 18 months (Table 5). Changes in marginal adaptation rates with time were significant ($p = 0.007$). Debonding was mostly observed in Ellis II.

Sensitivity to cold air and percussion sensitivity, surface roughness, secondary caries, and vitality loss were not observed at the end of 24 months (Table 5). Although changes in marginal discoloration over time were not significant ($p = 0.194$), changes in color match were significant ($p = 0.029$).

Table 4 Distribution of traumatic dental injuries according to the Ellis classification and location on dental arch

		Tooth number	Ellis I		Ellis II		Ellis III		Total	
			n	%	n	%	n	%	n	%
Maxilla (n = 70)	Right	11	4	5.5	24	32.9	2	2.7	30	41.1
		12	–	–	3	4.1	1	1.4	4	5.5
		13	–	–	1	1.4	–	–	1	1.4
Left	21	9	12.3	22	30.1	1	1.4	32	43.8	
	22	2	2.7	1	1.4	–	–	3	4.1	
Mandible (n = 3)	Left	31	2	2.7	–	–	–	2	2.7	
	Right	42	–	–	–	–	1	1.4	1	1.4
		Total	17	23.3	51	69.9	5	6.8	73	100

Table 5 Scores of evaluated criteria at the 6-, 12-, 18-, and 24-month follow-ups

	6-month follow-up			12-month follow-up			18-month follow-up			24-month follow-up	
	Alpha n	Bravo n	Charlie n	Alpha n	Bravo n	Charlie n	Alpha n	Bravo n	Charlie n	Alpha n	Bravo n
Percussion sensitivity	72	–	–	–	–	–	–	–	–	–	–
Sensitivity to cold air	72	–	–	–	–	–	–	–	–	–	–
Color match	70	2	–	65	2	–	53	5	–	52	5
Marginal adaptation	69	3	1	65	2	5	56	2	4	53	3
Anatomic form	71	1	–	66	1	–	56	2	–	54	2
Surface roughness	72	–	–	67	–	–	58	–	–	56	–
Marginal discoloration	69	3	–	64	3	–	54	4	–	53	4
Secondary caries	72	–	–	–	–	–	–	–	–	–	–

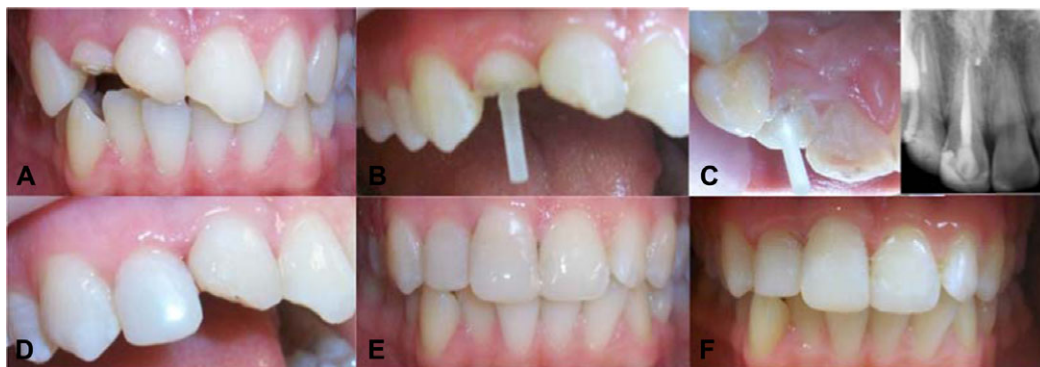


Figure 1 A clinical case representing insertion of fiber post and restoration of three traumatized teeth (A) preoperative, (B) buccal view of fiber post, (C) palatal view of fiber post and X-ray, (D) completed restoration, (E) 1 year, and (F) 2 year.

Discussion

Most dental trauma studies have focused on specific subpopulations, such as children from public or private schools, localized geographical sites, or limited age groups. Furthermore, most available dental trauma data have been retrospectively collected from cross-sectional studies or from longitudinal studies of patient records.¹⁹

In this study, the time elapsed between trauma and dental assessments varied from 1 day to 58 years. This long post-traumatic period may be attributed to lack of dental knowledge, attitude, and an effective venue for oral health promotion. In an Australian rural center study,³ only one-third of the patients applied for dental treatment within the day of the injury, whereas the rest delayed treatment for up to 1 year. Also, the time elapsed between trauma and restoration had an important

effect on retention of the restoration, because fresh dentin is more receptive to bonding.² Besides, occlusion and space of fractured area would alter after an extended period.

With respect to age, gender, location, and causes of trauma, the distribution of dental trauma of this study was similar to other Turkish^{1,26} and international studies.^{4,27} In this, dental trauma was frequently observed in the 17-to-24-year-old age group, but frequency of trauma was similar between age groups ($p = 0.781$). This result was in accordance with a study performed by Zengin *et al*² and a Brazilian study²⁸ and may be attributed to young people engaging in physical activities. A male/female ratio of 1.125/1 was reported in this study. This result was lower than Ajayi *et al*¹⁹ and Bücher *et al*'s studies.²⁹

In this study, falls were the major cause of injuries (58.8%) in both genders and in all age groups. Corroborative results can be found in the literature.^{3,30} Enamel and dentin fractures without pulp exposure (Ellis II) were the most common type of dental injury in maxillary central incisors, as observed in many studies.^{27,30,31}

In this study, both esthetic and functional properties were considered for the restoration of traumatized anterior teeth. Composite resin restorations were chosen after the treatment plan was discussed with the patient, because the treatment was a minimally invasive, functional, economic, and esthetic approach with a shorter implementation time.

Hybrid composite resins have been indicated for restorations in the anterior region,³² as they have a greater fracture resistance because of their inorganic fillers. On the other hand, it was reported that an etch and rinse adhesive system with bevel preparation significantly improved resistance to fracture.³³ This procedure allows a gradual decrease of bulk of the composite and masks the line between the material and tooth structure. Consequently, beveling may improve the esthetic results.

In this study, electric pulp testing was used as well as clinical examination. This test has a value in determining the vitality of the dental pulp; however, this test has some limitations and requirements such as an adequate stimulus, an appropriate application method, tooth isolation, and conducting media. The test may be frightening to patients, is sometimes painful, and can elicit a response from the periodontium.³⁴ However, if a tooth is suspected of having a pulpal problem, it was proposed in the literature that electric pulp testing should support thermal testing, as in this study.

The absence of sensitivity, surface roughness, secondary caries, and vitality loss at the baseline and at the 6-, 12-, 18-, and 24-month follow-ups indicated that the effective bonding to remaining tooth structure provided sufficient protection of the dentin/pulp complex. Overall, 8.6% of the restorations got a Bravo score for color match, and the change along time was significant.

The present results suggested that direct composite restorations bonded to fractured teeth had an approximate survival of 94% at the 24-month follow-up. The high performance of the restorations for marginal adaptation after this period can be attributed to both the effectiveness of the etch and rinse adhesive system used with incremental composite application technique and the presence of enamel for bonding; however, there were statistically significant differences in the marginal adaptation between the 6-, 12-, and 24-month follow-ups in this

study. The number of failed restorations increased over time. The only possible explanation could be related to involving the incisal edge, dimensions of the restoration, high masticatory loads, and lack of mechanical retention. It has been reported that large restorations have a high prevalence of failures.^{35,36} Also, class IV restorations tend to fail under high masticatory loads.³⁷ Besides, the lack of mechanical retention may lead to debonding in most restorations. All restorations included in this study were class IV and the above-mentioned reasons may lead to failure over time.³⁵⁻³⁷

Marginal discoloration usually originates from defects present between the restoration and the cavity margins or walls, inadequate finishing procedures, and insufficient bonding.³⁸ In this study, four restorations (7%) had a Bravo score for marginal discoloration. This may be related to the use of submicron hybrid composite resins, which have low coefficient of thermal expansion and higher inorganic filler content; however, significant changes in color match were observed in this study.

The composite resin restorations analyzed in this study showed a few anatomical variations. After 2 years, two teeth (3.6%) received a Bravo score. Sufficient conversion of monomer to polymer may result in an adequate resistance to wear.

To the best of the authors' knowledge, no clinical studies, except for some clinical reports, restored fractured teeth with composite resin. This may be the first study presenting etiologic factors and clinical aspects of fractured teeth. A total of ten restorations in five males (7 restorations) and two females (3 restorations) were debonded during a 24-month observation period in this study. Also, two females were adult (aged between 44 and 53 years old), while four of five males were adolescent (aged 15- and 16-years-old). A male predominance in debonding failures was observed. This result may be attributed to the age and gender of the participants. In this age group, males have a tendency of being more energetic and more active and choosing playing dangerous games than females.³⁹ Higher physical activity could lead to falling, collision, or sports accidents, which can result in refracture or debonding of their teeth.

The limitations of this study are largely due to its nature and short observation period. Selection bias is intrinsic to this type of study; to minimize this, during the recruitment period, all patients who presented with fractured anterior tooth were included in this study. Further long-term studies are needed.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1. The direct restoration technique was considered to be clinically acceptable 24 months after restoration.
2. Gender and age may be determining factors in the survival of direct composite resin restorations performed on fractured anterior teeth.

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